AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852

TRANSACTIONS.

(Vol. XIV.—March, 1885.)

DISCUSSION ON ENLARGEMENT OF THE ERIE CANAL—Continued.

A. P. BOLLER, M. Am. Soc. C. E.—In discussing the canal question, in its commercial aspect, we should not lose sight of the mode in which the canal business is conducted, before concluding that the Erie Canal cannot pay as against the railroads. It would seem, at first sight, that with a free waterway, open to all, the Erie Canal would have afforded the extreme possibilities of cheap water-carriage. In point of fact there is more discouragement over the outlook of the future for the freighters and boatmen, than in the days of tolls. Freights have been cheap enough, but scarce, and it would appear that there is something besides cheapness needed for the canals to prosper. Time of transit is more or less of an element, but just how much this enters into the question, it is difficult to estimate.

There is one phase of experience the canal has not as yet passed through, and that is a businesslike conduct of its affairs. It would be an interesting experiment to devote a reasonable time to operating the canals through the medium of a private organization, where the same business methods, economies, systems and brains could be put in force, as are now availed of by railways. At present there is no organization whatever in the business of the canals. The freighters and boatmen

form what may be called a *transportation mob*. System is just as impossible as it would be on a turnpike, where every man with a horse and wagon was looking for a load, in competition with his neighbor, with not enough to go round, and no one off in the back country seeking to draw business to the pike. There are used on the canals between 4 000 and 5 000 boats, averaging about 200 tons capacity, more than 95 per cent. being propelled by animal power. There are almost as many owners as boats, which they captain themselves. As a rule they are poor, and feel compelled to make every trip self-supporting. They have no capital or organization to secure business at its origin in the Western country, where it is contracted for by the railroads, which are represented by shrewd, active agents at every business centre. Consequently the boatmen have a chance only at such heavy freights as are consigned from Western points to Buffalo, and fight among one another for it after it arrives there. This diversity of ownership and interest has always been a fatal defect of the canal system of this State, killing it by inches after the first trunk line railway system was put in operation. This killing has been very rapid of late years, and final dissolution cannot be much longer postponed without a radical change of policy. A ship canal would have the advantage of affording water facilities for original cargoes from every lake port, meeting the railroads on their own ground, and would unquestionably command a large volume of traffic. Just what expenditure would be warranted, in building such a great work as the ship canal outlined by Mr. Sweet, involves an analysis of a vast amount of commercial and traffic data and the laws of transportation, that could only be authoritatively arrived at by a State Commission. There is that in the problem which would be well worth the State's best effort to thoroughly examine, through a well planned survey, and it is to be hoped that a high class commission for so doing will, in the near future, be constituted. In the meantime, as a last test of canal versus railway, no time should be lost in abandoning the present canal mob system, lease the canals, or hand them over free to a private corporation under all needed restrictions, and try what business methods will do in solving the canal problem. If that experiment did not yield satisfactory results, the palm must be given ungrudgingly to the railways. By that time all exact information will have been accumulated regarding a ship canal, and wise conclusions as to the canal problem may be reached.

Mr. E. H. WALKER, Statistician of the New York Produce Exchange (by letter).—Unable to be present at the discussion, I can only write briefly as to a few prominent points.

An improved canal is much to be desired. This is an age of telegraphs, telephones and all like appliances for giving quickly all sorts of information. Transportation must follow in their wake, and be also rapid and cheap.

With an abundance of money, $150 000 000 to $200 000 000, a ship canal from Lake Erie to the Hudson River is possible. Such a canal will be too expensive and too slow for the requirements of the country, and it would take a half century to construct such a work, on such an extensive scale, and when constructed and put in use it would be found impracticable to run large lake vessels from Chicago or Duluth to New York. It would be impracticable because it would not pay to do so.

Such large vessels, carrying 75 000 to 90 000 bushels of grain, would cost upwards of $100 000 each, and would be required to be manned by 25 to 30 men. Such a vessel must on an artificial channel move slow, and the round trip between Lake Erie and the Hudson, with this expensive vessel and expensive crew, could perhaps be made in a month.

The cost of transfer is not to exceed ¼ cent per bushel from the lake vessel to canal boats. There could be an improved canal not costing more than $3 000 000, and some say less than $2 000 000, that would better serve the interests of the country. Give the present canal ten feet depth of water through its entire length, leaving the miter sills as they are, give as much length to the locks as the present wall chambers will allow, using a tumble gate, as on the Delaware and Raritan Canal, use steam canal boats, good model for speed, and tender of like model, both carrying 18 000 to 20 000 bushels of grain, and making the round trip between Lake Erie and New York in eight or ten days. This would give celerity of movement, and the cost of the tow-boats would not exceed $15 000, versus $100 000 to $120 000 for the large lake vessel, a crew of four to six men, versus 25 to 30 for the lake vessel. This result could be attained in ten years.

The State Legislature might vote for the expenditure of 2 000 000 to 3 000 000 of money, but never for 150 to 200 millions.

E. S. CHESBROUGH, Past President, Am. Soc. C. E. (by letter).—In regard to the proposed radical enlargement of the artificial water-way

between the lakes and the Hudson River, my knowledge of the details of the freight business to be accommodated, and of the topography through which the enlargement would pass is too limited to permit me to speak with much confidence. It strikes me in a superficial way that the importance of the subject to the State and City of New York is such as to render it advisable to make the surveys and estimates recommended by Mr. Sweet, and if the Society is to vote on the subject I should like to be considered as voting *aye* on the question. It occurs to me that it would be well to study the experience not only of New York but of the West, in regard to the diminished amount of freight on our navigable rivers and other water-ways, since the railway system has been brought to its present state of efficiency. It is wonderful to hear of the decline of boating interests on the Mississippi and Missouri Rivers and their branches within the last thirty years or less, and even on our great lakes.

It may not be known to the members of the Society generally that our late excellent and much lamented fellow member, Mr. J. B. Jervis, once reported upon a project which had a similar object to that proposed by Mr. Sweet. I think it was called the Caughnawaga Ship Canal, or something like it. I once had a copy of the report, but unfortunately it was destroyed in the great fire of 1871. According to the best of my recollection Mr. Jervis' route passed down the right side of the St. Lawrence to the outlet of Lake Champlain, and thence utilizing that lake as much as possible on the way to the Hudson River.

W. W. Evans, M. Am. Soc. C. E.—There are but few people in or out of New York who have ever stopped to study the vast problem involved in the enlargement and improvement of the great artificial waterway that runs through the State of New York, and now brought to your attention in the short but clear and forcible paper of Mr. Sweet; he could not in the whole range of questions connected with the continuance and enlargement of the power and wealth of the City of New York, have touched on a subject of greater importance. The people of the City of New York have been now for over a third of a century wrapped up in the belief that the days for canals had gone by, and that railways were to do all the work, *better* and *cheaper* and *quicker* than it had been done, or could be done by any water-line, and this great fallacy has been fostered and kept alive by the preachings of the Railway-magnates dictated by their greed of gold and personal interests. It is very easy to

show that of the three pins this railway fallacy stands on, two of them (better and cheaper) can be knocked from under it, and then it must stand on one pin, that of speed, which no one will deny, and all students in the matter of transport will admit that when speed is not brought in as an element in the calculation, no railway can stand in competition with a well constructed water-line; this is clearly proved by statistics recently published, showing that the average charge on a bushel of wheat from Chicago to New York in 1884 to September 1st was, by lake and canal 6.60 cents, by lake and rail 9.75 cents, and by all rail 13 cents; these figures tell the whole story. If New York City is to maintain its supremacy as the Empire City of this Continent, it must do all in its power to improve and make more powerful its water-lines; it will be a sorry day for the City of New York when the Erie Canal, the water-line that made the city, is sold or filled up, or a railway put on its bottom or its banks, by the railway grabbers who have been for years trying to wreck it; they are not Patriots, Statesmen, or true Americans. Mr. Albert Fink's valuable papers on transport show the influence of the Erie Canal, and how widely it is extended, even down to the lines of the Railway he directed in Kentucky. The railway grabbers know and feel that as long as it exists it will exert a large, a very large influence on the cost of transport between the Atlantic coast and the great chain of lakes; no policy can be so suicidal as that of selling it or closing it, and no policy can do so much good and do so much towards extending the wealth and influence of the State of New York, as that of enlarging and improving in the most perfect manner this great water-line as pointed out by Mr. Sweet in his able paper, making it a ship-canal equal in carrying capacity to the new Welland Canal. I would propose, in addition to what Mr. Sweet outlines, to make a branch canal ten miles long of equal capacity, from Great-Sodus-Bay (the largest and best harbor on the entire chain of lakes) to the main line of the Erie Canal, to provide for catching the products of the West that may be dropped on to Lake Ontario by the Welland Canal, and also to provide for catching the great trade that will be thrown on to Lake Ontario, when the Canadians cut a ship canal from Lake Simcoe to Lake Ontario at Toronto, and by that canal connect Lake Huron through Georgian Bay and Lake Simcoe with Lake Ontario, this canal will shorten the water-line from Chicago and Duluth to New York over four hundred miles. And then in viewing these immense works we must not overlook the vision of a great ship canal that may some day

be built from Lake Superior up through Rainy Lake to the Lake-of-the Woods, and thence through Lake Winnepeg and Lake Manitoba into the heart of the greatest grain field of the world, all of which can be made tributary to the great centre water-line of the State of New York. Then, it may be, that a ship could load near the Rocky Mountains and unload in Liverpool or London; all this may be carried out, but it will not be done without a struggle, a bitter struggle with the railway interests.

If the people are true to themselves, they will show that the products of the forest, the field and the mine are so bulky and heavy in proportion to their value that they demand to be carried by water-lines, and the true interest of the country consulted instead of the pockets of the railway men. Mr. Sweet shows that the propellers on the lakes have found a profit in carrying grain at two cents a bushel from Chicago to Buffalo. Is it not reasonable to suppose that when we have a ship canal from Buffalo to the Hudson River, and have greater economies growing out of improvements in ships and steam propulsion, that we can carry with profit a bushel of wheat from Chicago or Duluth to New York for three cents?

The average freight charge on water lines from Chicago to New York on a bushel of wheat was, in 1857, 26.03 cents, and in 1884 it was 6.60 cents. This reduction in 27 years is so astounding that we are warranted in believing in future reductions, when we have finished a great ship canal, reduced the length of the route, built vessels of thin plates of steel and made the steam engine, which is to occupy only half the space it does now, give off a horse-power for every pound of coal consumed. These are glorious visions but they are all within the limits of "plain-sailing." Mr. Sweet starts his paper with the assertion that DeWitt Clinton was the projector of the Erie Canal; this is a popular error. Gouverneur Morris, the statesman, the man who wrote the Constitution of the United States, and who devised and gave us our decimally divided dollar, was the projector of the Erie Canal (see his letter to General Henry Lee, written in January, 1801, in the third volume of his life and writings). DeWitt Clinton, by his energy, his influence and his great executive ability, carried through that great work (great for those days) to completion, and by so doing made New York City the Empire City of this continent, and at the same time built up the West which to that time had been but a howling wilderness. It is not generally known that the first idea Morris had of this canal was

to build it without locks and have one continuous water-grade from Lake Erie to the Hudson River, and let the waters of the lake flow the whole distance. What a grand idea, and it was not so unreasonable as one would suppose at first sight, for the grade could have been kept to one foot fall in a mile, which is not impracticable for navigation, as the Ganges Canal in India, built for irrigation and navigation, and worked in either direction, has a grade of fifteen inches to the mile. Morris also had an idea that at some point on the south shore of Lake Ontario, a place could be found where a branch canal could be cut, and have the same grade into the main line. The topography of the State was not well known in those days. Mr. Sweet's idea of having but one summit, and that to be Lake Erie, is a grand one, and will be essential to the success of this great project. It is to be hoped that the members of our Society of Civil Engineers will look on it as one of the grandest projects of this age, so replete with gigantic works, and unceasingly advocate its being looked into and elaborated by the best engineering minds of the country.

The time is not far distant when there will be annually in the West, tributary to the great Lakes, over 50 000 000 of tons of the products of the forest, the field and the mine seeking tide water on the Atlantic. Now if we can save by this canal on a bushel of wheat or its equivalent in other products of this vast amount one cent, it will amount to $18\frac{2}{3}$ millions of dollars, and if we can save the difference between 6.60 cents and 3 cents, hinted at as in the possibilities, then the saving by making this great water line would be over 65 millions of dollars annually, a sum worthy of deep study and consideration. In discussing this canal matter I beg to bring to your attention the use of Elevators in the place of Locks, and to make them of chemically prepared wood instead of stone. I believe that wooden elevators can be made to lift with certainty and safety any vessel and its cargo, one hundred feet or more at one lift, no matter what the size or tonnage may be; and I further believe that these wooden elevators can be made cheaper and more durable than stone, and that by their use a great saving in time can be effected at such points as Cohoes, Little Falls, Lockport and wherever a number of locks can be combined in one lift or elevator; and I further think, from the facts laid before me in the history of Simpson's Wooden Dry Docks (eleven of which are now in use in this country), that they are much better in cold climates than any stone dock or lock,

and will cost less for yearly repairs; that I may not be misunderstood in this matter of the use of wood, I would mention that my idea is to wash out the interior of each stick of timber by the Boucherie process, in that way getting rid of the sap, which contains the germs of decay, and then by filling the capillaries of the wood with two chemicals; first one, and then the other, which chemicals coming in contact inside of the timber, form an insoluble salt which will remain there, and being both from inorganic matter, they will render the wood almost uninflammable and almost indestructible by decay.

The chemicals I would propose are cheap and readily manufactured anywhere; they are silicate of soda and chloride of calcium.

With such a canal as Mr. Sweet has proposed the farmers of the West can keep in check the whole railway system; it can stop growing wheat in England, and can defy any rivalry from India. To show what great differences there may be in different modes of transport, I beg to mention that in 1857 I had sent from New York to Valparaiso, while building a Government railway in Chili, 5 000 barrels of cement, that cost for freight 5 dollars a ton on a voyage of 11 000 miles; this same cement cost $35 a ton to transport it in ox-carts from Valparaiso to Santiago, a distance of 100 miles. Within a short time I have sent an iron structure to South Africa that cost for freight from New York to Port Elizabeth, in Cape Colony, $8 a ton, and then it cost £40 a ton ($200) to haul it to Bloemfontein, in the Orange Free State, something over 300 miles. A considerable part of this route is occupied by a baby railway (narrow gauge); the railway of the future, according to Mr. Fairlie; but we are not yet far enough into the future to see where its merits come in, for this particular railway in Cape Colony has not yet been able to take the business of transport away from the carts.

T. C. Clarke, M. Am. Soc. C. E.—Money can do anything, and money enough could make this ship canal. Assume that it would cost no more than Mr. Sweet's estimate, say $150 000 000:

Interest at 5 per cent. would give an annual charge of.....	$7 500 000
Repairs, say 2 per cent.....	1 500 000
	$9 000 000

Assume also that its tonnage would be, as Mr. Sweet thinks, 25 millions annually. The toll per ton would be 36 cents, equal to a little over 1 cent per bushel.

No one will doubt that it would take a 1 500 ton propeller as long, if not longer to go from Buffalo to New York, as from Chicago to Buffalo. If as long, which I doubt, on account of the delays of locks, side winds, passing other vessels, etc., then the cost would be the same, viz., 2 cents per bushel. Add tolls, 1 cent, we have 3 cents per bushel as against 4 cents, a saving of only 1 cent.

There is another point to be considered.

Why is it that the canal carries only $\frac{1}{5}$ of the freight, and the railroads $\frac{4}{5}$, when the cost is so much less? It is because the canal is shut up half the year, while the railroads are always ready.

I believe it would be a wiser investment of capital to lay steam pipes to heat the canal and keep it open all the year, rather than to build Mr. Sweet's proposed ship canal.

N. M. EDWARDS, M. Am. Soc. C. E.—One of the great economic questions to-day before this nation is, can our great northwest continue to raise wheat, at a fair profit, and compete with other favored wheat growing countries in the markets of Europe. In the past it has been done, and mainly through more enlightened energy, rather than through advantages of soil or location.

Three factors have chiefly aided in the race:

1st. The Erie Canal opening to the commerce of the world the shores of the great lakes.

2d. Our early railroad system, its ally and competitor.

3d. Our improved agricultural implements.

Now, other nations are availing themselves of our methods, some are near the great markets, with mainly deep water navigation thereto, and all have cheaper labor. In view of our wheat fields being so remote, we must cheapen our transportation by deep water navigation to the seaboard, that we may distance competitors and reap profit in the race.

The advantages of the general plan of deep river outlet of Lake Erie into the Hudson, as advocated by Mr. Sweet, State Engineer of New York, must, in my opinion, command recognition. If the State or general government will not move early, I believe a liberal charter should be obtained, protective and popular in its conditions, and that the people interested would undertake the work.

Upon this enlarged waterway, with New York the metropolis, and Chicago and Duluth at the head of navigation, capacious enough for the

commerce of the nation, would float steamships equally at home on the lakes or the ocean. With such facilities I estimate wheat could be carried from the head of the lakes to New York City at 5 cents a bushel, with 1 or 2 cents added, if tolls are required.

From prominent railroad authority we have the statement that from St. Louis by water, via New Orleans to England, wheat can be carried 8 cents per bushel less than by rail to Atlantic ports and thence by water.

For comparison, we will take St. Paul as a center, and estimate the future probable rates, say for 10 years hence, over the various routes to the seaboard. On the trunk lines from Chicago to New York City we are given in Mr. Sweet's paper the average of rates as 14.9 cents per bushel. Taking 940 miles as their average length we have wheat carried 63.1 miles for 1 cent; then assuming a possible reduction of 20 per cent. in rates, we have a carriage of 79 miles for 1 cent. From St. Paul to New Orleans by barges I would place a rate of 8 cents, or about the present average from St. Louis to New Orleans.

Below are estimates of possible rates under the more favorable conditions for cheap traffic that may exist a decade hence:

St Paul by all rail to New York City via Chicago,
about 1 340 miles.....17 cents per bushel.
By all rail to Montreal via Sault St Marie, say
1 150 miles.....14⅔ cents per bushel.
By rail to Duluth, 155 miles, with ½ cent transfer,
thence by proposed improved water route to
New York City..... 7½ cents per bushel.
Down the Mississippi River to New Orleans..... 8 cents per bushel.

The capitalists of New York and the East will not desire to see the commerce of the West diverted by reason of the Welland Canal and Eads Jetties, when engineering works equally practicable will furnish a cord that will bind that commerce to themselves. The manufacturer, requiring low freight rates, that he may be able to compete with the world, uniting with the producer and consumer, will demand that the water ways be not blocked by want of proper increase of facilities. The nation can be relied upon for the deepening of the St. Clairs Flats and the Sault St. Marie, and will be enriched, strengthened and united by this strong bond of steamship communication from New York City to the great northwest.

Col. W. E. MERRILL, M. Am. Soc. C. E.—The project prepared by Mr. Sweet is a magnificent one, worthy of the great and wealthy nation to which he has presented it. The benefits to follow from its adoption will not be limited to the State and City of New York, but they will be spread over the entire basin of the great lakes, and they will ramify to all parts of the great northwest, the granary of the continent.

Money expended in transportation is practically money wasted, inasmuch as it adds nothing to the intrinsic value of the thing transported. It is a waste that can never be wholly avoided, but nevertheless it is a waste, and every consideration for national welfare calls upon us to reduce it to the minimum, every such reduction being a practical addition to national wealth. Bread is the staff of life, and whatever reduces the price of bread makes it easier for the laboring classes to sustain life, and to bear the burden of poverty. In all communities the great majority of the population must necessarily be dependent for their sustenance on their daily labor. The products of this labor are exchanged for food, clothing and shelter, and whatever reduces the cost of the chief article of food gives the laborer a larger surplus to expend on the comforts of life, thus making him more contented with his lot, and less disposed to wage war against society.

The chief merit of the project in question is that it will reduce the cost of wheat, and therefore of bread, to what we may consider the theoretical minimum; the benefit that will flow from a radical cheapening of the chief article of human food is beyond calculation. Cheap bread is a guarantee against such starving mobs as began the French revolution, and in these days when the poor are said to be growing poorer, it is a matter that deserves most serious attention. A nation can well afford to expend large sums in assisting the masses to earn their daily bread without excessive labor.

The main question, however, with which we have now to deal is the practicability of the project from the standpoint of the engineer. I have examined it with care, and feel free to express the opinion that it is entirely practicable. The current that would be created in the western portion of the canal by the effort to feed the whole line from Lake Erie, would undoubtedly be somewhat objectionable, but it will be in favor of the heavy traffic, and it can be lessened by retaining all the intermediate feeders of the present canal, and by concreting the bed and banks at points where the leakage is above the average.

There is no serious difficulty in making or handling canal gates of the size and lift required. For a lock having a lift of 25 feet, a draught of 18 feet and a width of 60 feet, the lower gates would have to be about 45 feet high and 35 feet wide. There are now in daily use on the Louisville and Portland Canal, gates that are 31 feet high and 47 feet 8 inches wide, and on the St. Mary's Canal, gates that are 39 feet high and 35 feet wide; the former are worked by steam, and the latter by hydraulic power. Some similar arrangement would be required at the proposed locks, but the fall over the waste weirs can be utilized at a minimum of cost.

The author suggests the use of "movable" dams on the Mohawk. I would recommend fixed dams, because they are cheaper in first cost and in maintenance, and for the additional reason that no movable dam has yet been built with a greater height than 14 feet. A movable dam with 12 feet lift, and 18 feet depth of water below it, would require movable apparatus 30 feet high. There are types of movable dams that could be enlarged to these dimensions, but the apparatus would be very costly and very heavy; it could only be handled by power, and therefore its use should be avoided, unless absolutely essential. Movable dams are a necessity on the Ohio, and on the lower part of the Great Kanawha, because during half of the year these rivers are abundantly supplied with water, and, at such times, dams that cannot be gotten out of the way are not only undesired, but they are positive obstructions to navigation. Movable dams are also required on rivers that have low banks, and valuable lands adjacent to the stream that would be overflowed during floods by fixed dams. In all other cases fixed dams are preferable, as they cost less to build, are cheaper to maintain and operate, and they can resist the shock of moving ice, which movable dams cannot do; the latter are always lowered whenever ice threatens. As I am not familiar with the physical conditions and surroundings of the Mohawk River, I submit these remarks with diffidence.

The standard draught for harbors on the Great Lakes is 16 feet, and this draught will not be exceeded until the movement for an increase becomes general. The St. Clair Flats Canal, to which allusion is made in the paper, is merely an open cut with banks protected by dikes. It is 300 feet wide, has a depth of 16 feet for a width of 200, and is a trifle over 1½ miles long. It is maintained by occasional dredging, and by the same means it can be deepened, but any marked increase in depth

would necessitate a corresponding increase in length, as the whole northern end of Lake St. Clair is shoal.

The St. Mary's Canal is at the outlet of Lake Superior, and it is consequently only used by the commerce of that lake; the great grain fleet from Chicago and Milwaukee passes 50 miles south of it. The only limit that there is on the size of vessels coming East from Lake Michigan is a limit to their draught caused by the shallowness of lake harbors, and of Lake St. Clair.

The present Erie Canal is 352 miles long, and has 72 locks with an average lift of 9 feet. The new water route will consist of a canal 245 miles long, with 6 locks having an average lift of 23 feet, and 100 miles of slackwater. A mere comparison of these figures will show at a glance how radical a change, and how vast an improvement, is outlined in Mr. Sweet's paper.

I apprehend that there will be more real difficulty in securing 18 feet in the upper Hudson than in any other part of the project, but a lateral canal is always possible should the open river prove impracticable.

The great military advantages of the proposed ship-canal should not be overlooked. Under existing treaties with Great Britain the United States can only keep one gunboat of limited tonnage on the Great Lakes. In case of war Great Britain could command an unlimited supply of gunboats through the Canadian canals, while we would have to depend on merchant steamers hastily transformed into what were known during the late war as "tin clads." With the proposed ship-canal we could meet a foreign foe on a footing of equality, provided, of course, Congress should meanwhile awake to the defencelessness of the nation and give us a navy.

JOHN D. VAN BUREN, JR., M. Am. Soc. C. E.—Features of the Various Routes.—This is a century in which Titanic schemes are not only suggested, but carried out, and possibly the present generation will see a ship canal built from the lakes to the Hudson River. As a purely engineering project, the work proposed in the paper under discussion is undoubtedly feasible, and, considering the requirement that the route shall lie wholly within the limits of the State, it is perhaps the best one for such work. Indeed, there is but one other answering this requirement: that by canal around Niagara Falls, Lake Ontario and Oswego. There are, however, two international routes worthy of serious consid-

eration. The important features of the four routes are set forth in the following table:

TABLE No. 19.

Routes.	Lockage.	No. of Locks.	Miles, Canal.	Miles, River.	Miles, Lake.	Total, Miles.
1. Chicago to New York, by Buffalo and Erie Canal	655	72	352	202	865	1419
2. Chicago to New York, *via* Welland Canal and Oswego	955	94	224	196	983	1403
3. Chicago to New York, *via* St. Lawrence and proposed Caughnawaga Canals	717	72	158	363	1116	1637
4. Chicago to New York, *via* proposed Ottawa and Caughnawaga Canals	872	87	125	572	671	1368

(In the Oswego route the Welland Canal is taken to represent a similar canal on the State side.)

The time which would be required from Chicago to New York by each route respectively, is as follows, the estimates being based upon a speed of 5 miles on canal, and 12 miles on lake and river, and 30 minutes being allowed for each 20 feet of lockage.

1. Erie route..... 176 hours.
2. Oswego route..... 167 "
3. Niagara Falls and Caughnawaga..... 173 "
4. Ottawa and Caughnawaga..... 150 "

The Oswego route is deficient in water. and would require a costly feeder from Lake Erie, necessitating for that purpose a material enlargement of the western portion of the present canal, and an expensive alteration between Newark and Syracuse, in order to secure a continuous descent. It is probable, therefore, that this route would be more expensive than the first.

There are no difficulties of this kind on the two international lines, which would evidently be incomparably cheaper, and, one of them, a day shorter. It is then an important question whether the advantages of such an international route would outweigh those of the more costly and longer State route. Probably a full State control would be of imperative importance.

Cost of Construction.—Before even a preliminary discussion can proceed with any satisfaction an estimate of the cost of the proposed work

must be made. A rough approximation can perhaps be made from the cost of the present Erie Canal. The total cost of the Erie Canal, not including interest, during construction (about $9 000 000), and exclusive of feeders, was, up to 1876, about $48 000 000. Of this were expended for

Bridges, about	$3 000 000
Locks, about	5 000 000
Aqueducts, about	7 500 000
Culverts, stop-gates, &c	1 000 000
Total	$16 500 000

If the cost of the canal, exclusive of structures, be taken as proportional to the area of the water-way, the estimate will certainly be low, for where embankments occur this ratio would be greatly exceeded.

Hence, approximate cost of prism—

$$= \$31\,500\,000 \times \frac{1800}{490} = \$116\,000.$$

The bridges may be taken as proportional to the square of the width of water-way, equal to about $6 000 000.

Say, 15 locks of about	25	feet lift, at	$1 500 000 =	$22 500 000
15 "	12	"	500 000 =	7 500 000
Total for locks			=	$30 000 000

The cost of aqueducts will evidently be great, and may be taken to hold the same ratio to the cost of locks as obtains in the present canal, making a deduction of one-third for absence of aqueducts east of Utica by reason of the proposed canalization of the Mohawk.

Hence, cost of aqueducts = $30 000 000.

In a similar manner, culverts, &c., = $5 000 000.

SUMMARY.

Prism,	=	$116 000 000
Bridges,	=	6 000 000
Locks,	=	30 000 000
Aqueducts,	=	30 000 000
Culverts, etc.,	=	5 000 000
Add for dams,	=	7 000 000—About as much as Mohawk locks, including consequent land damages.
Grand total...		$194 000 000

If the work were built in ten years, the interest charge would be about 25 per cent., making a total cost of $242 500 000, say, $240 000 000. This is about three (3) times the estimated cost of the Nicaragua Canal, which is only about one-third as long, if I correctly remember Mr. Menocal's amended figures, and a little more than three times the actual cost of the Suez Canal, $89 000 000, which is only 100 miles long, and has no locks. This estimate, though crude, is, perhaps, not too wide of the mark to serve as the basis of a preliminary discussion of the commercial part of the problem.

Cost of Transportation.—The time of a trip from the western centre and cost of construction having been thus approximately determined, an estimate may be made of the benefits likely to result from such an improvement in transportation facilities. There is but one test, the usual commercial one, *will it pay;* would the cost of transportation be sufficiently reduced to compensate for the outlay? This test is as true for a government work as for a private one, and whether the canal be free or not. Unless the cost of transportation would be materially reduced below the cheapest present normal rates, the enterprise would prove a failure, nor would it benefit the State or its people.

The interest charge would be, at 5 per cent.....	$12 000 000
* The annual cost of repairs and management, at least.....	4 000 000
Total.....	$16 000 000

Taking the total tonnage at 20 000 000, the movement may safely be taken at 8 000 000 000 ton-miles from Buffalo to New York, the through traffic being taken at about two-thirds of the whole. This gives a charge for the support of the canal $= \frac{16\,000\,000}{8\,000\,000\,000} = 2$ mills per ton-mile = 5 cents per 100 pounds, and 3 cents per bushel of wheat from Buffalo to New York. Mr. Sweet states that a profit was found during the past season in a lake rate of 2 cents per bushel from Chicago to Buffalo, and estimates that an equal rate from Buffalo to New York would cover the freight by the proposed route, or a total of 4 cents from Chicago to New York. I think this entirely too sanguine, and that about 3 cents for each distance, or 6 cents from Chicago to New York, would prove

* The annual expenses of the Suez, only 100 miles long, are about $4 000 000.

to be the minimum paying rate. Estimating for both rates, there results:

1. Rate, 4 cents from Chicago to New York, total cost of transportation $= 3 + 4 = 7$ cents per bushel.

2. Rate, 6 cents from Chicago to New York, total cost of transportation $= 3 + 6 = 9$ cents per bushel.

These two estimates may, perhaps, be considered the maximum and minimum probable cost by the proposed route, and when compared with the cheapest present cost, the measures of the probability or possibility of turning an adequate tonnage into the proposed channel, upon which the true economy of the scheme would depend. It is necessary, then, to compare these figures with the present normal rates by the cheapest routes. Mr. Sweet gives the following:

All rail, $14\frac{9}{10}$ cents per bushel, Chicago to New York.

Lake and rail, $12\frac{1}{10}$ cents per bushel, Chicago to New York.

All water, $9\frac{9}{10}$ cents per bushel, Chicago to New York.

TABLE No. 20.

‡ TABLE SHOWING THE ESTIMATED COSTS OF TRANSPORTATION OF FREIGHT BETWEEN BUFFALO AND NEW YORK, BY VARIOUS MODES OF MOVEMENT:

Number.	Mode of Movement.	Number of Round Trips.	Estimated Cost.						Per Cent.
			Exclusive of Tolls.			Inclusive of Tolls.¶ Elevating at New York and Trimming.			
			Per Ton	Per Ton Mile.	Per Bushel Wheat.	Per Ton	Per Ton Mile.	Per Bushel Wheat.	
				Mills.	Cents.		Mills.	Cents.	
1	By animal power.....	7	$1.896	3.83	5.688	$2.24	4.53	7.378	99.
*2	By Baxter steamers...	10	1.92	3.88	5.76	2.265	4.58	7.45	100.
†3	By Belgian system...	8	1.741	3.52	5.22	2.085	4.21	6.91	92.7
†4	Do. ...	9	1.596	3.22	4.79	1.94	3.92	6.48	87.
§5	By steamer and consort.....	9	1.574	3.18	4.72	1.92	3.88	6.41	86.
§6	By steamer and consort.....	10	1.55	3.13	4.65	1.895	3.83	6.34	85.1

* Single steamers propelled by screws.

† Cable in bottom of canal, steamer and tow.

§ Screw steamer pushing consort ahead, both loaded.

¶ Tolls, 1.04 cent; elevating at New York, ½ cent; trimming, $\frac{15}{100}$ cent.

‡ Report of State Engineer and Surveyor on Canals of New York, 1878, p. 56.

Table No. 20, prepared with great care by the writer while State Engineer and Surveyor, from data collected from numerous reliable parties actually engaged in transportation on the canal, exhibits the estimated cost on the Erie Canal by the various modes in use. The interest and sinking funds are based upon a rate of 7 per cent.; a change to 6 per cent. would vary the figures not more than 1 per cent.

These figures may, I think, be taken as the lowest fairly profitable rates, considering wear and tear and living wages.

It will be sufficient to make the comparison with the present all-water route by the Erie Canal. Now, this can be done in four ways:

1st. By comparing the two canals as private enterprises, and charging full interest on total cost against both. A charge of about 3 cents per bushel from Buffalo to New York must then be made against the present canal.

2d. The Erie Canal, considered as a purely financial scheme, having fully paid for itself, including all interest charges, from its tolls, it may be looked upon as having cost the people of the State nothing. In this view, then, no interest charge should be made, but only the cost of operating, equal to about the rate of toll included in table No. 20, 1.04 per cent. per bushel.

3d. Considering the Erie only as a free canal, which gives the true comparison between the present cheapest route and the proposed canal built by private enterprise or run with full tolls.

4th. By comparing freight rates only, both canals being free.

Hence, Table No. 21.

Considered as a private enterprise. The third comparison of the table indicates what the inducement would probably be to turn an adequate tonnage into the new channel. The rates would be nearly the same as those of the present free all-water route; and it must be remembered that the traffic on the present canal does not equal one-half its full capacity, and yet, notwithstanding an annual average difference between the all-water and railroad rates of 5 cents per bushel, or one-third in favor of the former, its tonnage has not increased for years, while the traffic of the latter has increased enormously. This difference seems to be a measure of the superiority of railroad facilities over those of the present all-water route. The causes of this lie mainly in the fact that the water route is closed during five months, is on the canal *very slow*, and has poor terminal facilities. The proposed canal would, of course,

TABLE No. 21.

COST OF TRANSPORTING A BUSHEL OF WHEAT FROM CHICAGO TO NEW YORK.

MODE OF COMPARISON.	COST BY PRESENT CANAL.		COST BY PROPOSED CANAL.	
	Taking Freight from Chicago to Buffalo.		Taking Freight from Chicago to New York.	
	2½ cts.	3½ cts.	4 cts.	6 cts.
1st. Charging interest against both	11.84	12.84	7	9
2d. Charging only operating expenses against Erie	8.84	9.84	7	9
3d. Erie considered as a free canal	7.80	8.80	7	9
4th. Comparing freight rates, both free	7.80	8.80	4	6

remedy the last two faults, but there must always remain an important difference in favor of railroad facilities. Considering all the circumstances, it is scarcely probable that a private company would dare undertake the work.

Considered as an undertaking by the general government. If a private company would not undertake it, should the general government? But what interest, under the Constitution, has the Federal Government in such a project? To make it a military highway? In case of war with Great Britain, the policy of 1812 would be better, to build our lake war vessels on the lakes. We should be unable to spare even our fishing smacks from the seaboard for navigation on the great waterway. Again, as a commercial enterprise, the Federal Government would have as much constitutional right to undertake it as it had to appropriate over $80 000 000 (in a single year) for river, harbor and *other* improvements. The work would probably be distinguished by the same examples of public and private morals which marked the government's connection with the Pacific roads. Besides, it would be difficult to

induce Congress to appropriate the necessary funds for a sectional improvement likely to seriously damage the interests of several neighboring States.

Considered as a State enterprise. Should the State undertake the work it must be as a free canal. The last comparison of the table, then, indicates what the probable inducement would be to turn an adequate tonnage into the new channel, a rate from Chicago to New York of from 4 to 6 cents, instead of from $7\frac{8}{10}$ to $8\frac{8}{10}$ cents per bushel. Such a reduction would, undoubtedly, divert a very large tonnage to the new canal, and perhaps quickly double the traffic between New York and the West, gathering it from the railroads of other States, and from the natural increase due to such cheap rates. The general benefits would be those attending an enormous increase of all branches of business. For this the people would pay about $16 000 000 per annum.

It must, however, be considered that New York has already by far the cheapest highways to the West, and has, as a consequence, more than one-half the trans-continental trade, and fully one-half the foreign commerce. This pre-eminence has never been seriously threatened, and, whether the ship canal be built or not, it will ever distinguish the metropolis of America; the preponderance of its commerce will, indeed, inevitably increase. It is to be considered, too, that the present Erie Canal is not pushed to one-half its full capacity, and that by a moderate improvement of its waterway, locks, terminal facilities, and a radical alteration in its boats and motive power, a large reduction in rates may be secured. The development of the commerce of New York City will undoubtedly be slower without than with the ship canal, and the question remains, will it pay to hasten it by an annual expenditure of $16 000 000? If either government is to undertake the work let it be the one nearest the people directly interested. New York State can better afford to make her own public improvements than to let the general government undertake them, for she has poured millions into the Federal treasury for such purposes, and received only thousands.

D. Farrand Henry, M. Am. Soc. C. E.—It seems to me that if the discussion on the subject of water communication between the West and East is to be limited to the improvement of the Erie Canal, much that can be said as to the best method of cheapening the transportation of freight from the West will have to be omitted.

For with us the question is not solely how to best reach New York, but also how to reach Liverpool. Formerly, when there were 11 to 12 feet over the St. Clair Flats and the Lime Kiln Crossing, wheat was carried in light-draft vessels and propellers, and 4 cents per bushel was considered the lowest figure at which it could be taken from Chicago to Buffalo. But, with the deepening of the above named places to 14 feet, a new system was introduced—that of barges—now generally consisting of a steam barge and consort, the latter being in tow of the former, and together carrying from 100 000 to 150 000 bushels of grain, and a fair profit can be made at 2 cents per bushel.

Some years ago, when the Welland Canal was first opened, with 10 to 11 feet over the miter sills, lake vessels went through to Europe, but they necessarily were so small and of such light draft that they never paid, and the experiment has not been tried since.

But were a waterway constructed to the ocean allowing a draft of 16 to 18 feet, then our barges could go direct to Liverpool, and the increased draft would double their capacity, so that they would carry from 200 000 to 300 000 bushels, and the cost of transportation from Chicago to the seaboard would be but little if any more than it is now to Buffalo, while if there was no transfer there, the freight to Liverpool would be very much lessened.

Three plans for accomplishing this have been proposed: 1st. The route from Chicago to the Mississippi, by the Illinois River. 2d. The enlargement of the Erie Canal; and 3d. The deepening of the Welland Canal, and the improvement of the St. Lawrence.

In the first-named project the distance is, I believe, about 250 miles, of which only very short reaches of the rivers are deep enough to carry 18 feet, while before the actual seaboard is reached—beyond Key West—some 400 miles of westing has been made, and also 18 degrees of southing which has to be recovered in the ocean voyage. Besides a great objection to the transportation of grain by this route is the danger of heating in the lower Mississippi and the Gulf, which is a serious drawback. I have by me no estimates of the cost of this route, but it would be very large.

In the second plan Mr. Sweet makes the total distance 375 miles, of which about one third is new canal, and the balance enlargement of the old canal and canalization and improvement of the Mohawk and Hudson Rivers; and he estimates the cost from 125 to 150 millions of dollars.

This would undoubtedly be of great benefit, and the commerce of the lakes would be enormously increased, as during the summer months the railroads would carry but little of the through freight, as they could not possibly compete with the water transportation, and vessels would reach the seaboard in about the same latitude as Chicago.

But putting patriotism aside, and looking at the question only from a commercial and engineering standpoint, is not the third project by far the best?

The distance from Lake Erie to Quebec is a little over 500 miles, or about the same as to New York. Of this distance, 70½ miles is in canals, in 7 stretches, with 53 locks of 533½ feet aggregate lift. The Welland Canal is 27 miles long, and has already been deepened to 14 feet, and the Canadian Government is continuing the work in the other canals. Besides these, to deepen to 18 feet, perhaps 10 miles of the River St. Lawrence would have to be improved. This work ought not to cost more than 20 to 30 million dollars, and in many respects would be much better than a continuous canal.

For one thing, barges through the lakes and rivers make from 8 to 9 miles per hour, while in a canal they would probably be limited to 4 or 5 miles, which would make them about 3 days longer in reaching New York by the Erie Canal than Quebec by the St. Lawrence. Besides Quebec is 6 degrees north of New York, so that they would be that much further on their way to Liverpool. It might seem that being so much further north there would be earlier trouble from ice, but Western New York is nearly as cold as Montreal, and the St. Lawrence canals now close but little if any earlier than the Erie.

Therefore, it appears to me that by far the most feasible plan for a waterway to the coast is by this northern route; and if patriotism stands in the way, why annex Canada, canals and all.

One link in the chain I proposed some years ago, and obtained a bill to authorize its construction from the Canadian Parliament, that was a Canal from Lake St. Clair to Lake Erie, across a low peninsula, about half marsh and the rest sand not more that 30 or 40 feet above the lake. This canal, only 12½ miles long, would cut off about 90 miles of lake and river navigation, part of it through the tortuous and sometimes dangerous navigation of Detroit River. But Detroit was no place to get capital for such a project, and I had to drop it. Had it been done at that time the United States Government might have saved the half

million they are spending on the Lime Kiln Crossing, and the railroads could bridge Detroit River without trouble from the lake marine. I have no doubt, if ever a direct waterway to the coast is obtained, this canal will come in as part of the scheme.

O. CHANUTE, M. Am. Soc. C. E.—I hope that the discussion of Mr. Sweet's important and valuable paper will thoroughly cover the probable practical operation of such a waterway as he proposes, and the economy likely to result therefrom. There are a number of questions which I do not feel competent to discuss myself, but upon which I would like to have the opinions of canal engineers. They are as follows:

1st. Can the enlarged waterway be operated in practice at the speed which Mr. Sweet seems to have in mind? He proposes to construct an artificial river 100 feet wide at bottom and 18 feet deep, and he expects the large propellers of the lakes to pass through it, including detentions at the locks, at about half the speed at which they run between Chicago and Buffalo. This, I assume, must mean 7 or 8 miles per hour while in motion. The present canal, as I understand, is 52½ feet wide at bottom, and is navigated by boats averaging about 17 feet wide. Their proportions are, therefore, about ⅓ of the bottom width, while the lake propellers are about 40 feet beam, or say $\frac{4}{10}$ of the bottom width proposed by Mr. Sweet. Is it probable that the lake propellers being thus twice as wide in proportion, can attain a greater speed than the present steam canal boats (which are said to run 5 or 6 miles per hour), without injury to the banks of the canal, or detriment to themselves and other boats?

2d. What is to be done with the sailing vessels and barges now navigating the lakes? If they are to be towed through the canal in fleets by the lake propellers, will there not be undue detention at the locks? It is possible that the sailing vessels are destined to be supplanted by the propellers, but the barges are said to be an important factor in the economy which has been accomplished on the lakes?

3d. What is to be the fate of the present canal boats when forced into close contact with lake propellers in a narrow waterway? If we may reason from what happens on railroads, when large and small cars are mixed together in trains, the little ones will have a hard time of it.

Should these questions be deemed by canal engineers to present any real difficulty of operation, the alternatives would be either to reduce the speed, and consequently the anticipated economy, or to enlarge the

waterway proposed by Mr. Sweet, and also his estimate of 125 to 150 millions of dollars.

As for myself I have been expecting improvement from quite another direction to cheapen transportation on canals, and to restore prosperity to those of New York. Economy, as it seems to me, consists in substituting for animal power some form of engine for the propulsion of the present canal boats, and thus accomplishing for them what Stephenson did for the land carriage, and Fulton for the vessel, by their applications of the steam engine.

I do not believe, however, that the steam engine can be economically applied upon canal boats. For such small power as is there required, it is too complicated, and requires (including the boiler) too much attendance and skill, to compete successfully with the two mules which now draw the boats.

Practically, a steam engine of two or five horse power, requires nearly as expensive an engineer (and there cannot be less than one), as an engine of 100 horse power. The risk of breakage is as great, while the waste of fuel, and difficulty in maintaining a needed pressure, are greater in small steam engines than in large ones. There is a point clearly, or a certain amount of power below which it is not profitable to use steam instead of animal power, and that point, as I believe, is reached when we get down to the two or five horse power required to propel a canal boat.

It seems to me that the kind of engine required on the latter is one which shall be absolutely safe against explosion, is not liable to break down, that can be started up at five minutes' notice, and will stop consuming fuel when the boat is waiting, either to pass through a lock, or for some other cause. Above all, it should be so simple as to require no greater skill to run it than is possessed by the present mule driver, or, better still, be under the control of the steersman, so that he may manage it without material interference with his other duties. The latter arrangement would at once dispense with two drivers and four horses (night and day shifts), at the cost of fuel and repairs required by the engine. It seems to me that we have now such machines nearly perfected, in some forms of heat engines which have been introduced of late years. There is, for instance, a petroleum engine which is made in Boston and in New York, in which the power is obtained from the expansion in a cylinder of a mixture of petroleum vapor and air. It is said to cost no

more for fuel when running than a steam engine of equal capacity for the small sizes hitherto made. It feeds itself, and therefore requires no fireman; it is started and stopped by simply opening a cock, while when it does stop the consumption of fuel ceases.

There are also several forms of gas engines (of which the "Otto" is the best known), known to be safe, economical and easily managed. As now introduced commercially, they possess the same advantages as the petroleum engine, but they rely upon the street main for their supply of gas. For use upon a boat they would require the addition of a retort to generate the gas as wanted by the engine, and a number of patents have been taken out for this purpose. When this is successfully done the gas engine will have a wider application than the petroleum engine, because coal is both cheaper and more widely distributed than petroleum.

These various engines are not yet perfected. They are probably much in the same stage of development as was the steam engine when Watt began to experiment with it. I believe they can be much simplified in design, and made almost secure against breakage, so that the helmsman can manage them, and steer his boat besides, while at the same time their fuel economy can be increased.

If this can be done, a moderate expenditure of money for engine and screw propellers adapted to the present boats will materially cheapen canal transportation, while the speed may, perhaps, be increased to one as great as would be practicable with the plan proposed by Mr. Sweet.

The difference between the latter and my suggestion is, that while he proposes an enlargement of the waterway to permit the use of steam engines of economical proportions, I have been contemplating the introduction of a new engine adapted to the present size of the canal and of its boats. The question to consider is whether the cost of transferring at Buffalo and the lesser efficiency of small boats, if any, will be less or more than the interest on the cost of the great waterway proposed by Mr. Sweet.

I suggest, therefore, that the discussion be permitted to bring out the views of other engineers upon the practicability of applying some form of heat engine to the propulsion of canal boats. If the proposition be deemed sound, the discussion will have the effect of calling the attention of inventors to the need for such an engine, and may lead to some action from the State, or from private parties to bring the matter to actual experiment and trial.

CLEMENS HERSCHEL, M. Am. Soc. C. E.—In reply to the request of the Secretary, I desire to remark upon a few points only, of those which this paper brings to the mind of the attentive reader. One of these is the important subject of the regulation of railroad freight rates, by the encouragement or by the creation of water competition, rather than by a reliance, wholly, upon the work of railroad commissioners, or upon the successful enforcement of rigid statutes designed to forbid excessive and discriminating freight rates, under pains and penalties.

The line of argument will be this: three methods, or I might say four methods, have been suggested, advocated, tried, to control the rates for the transportation of freight, and to prevent discrimination, namely:

(1.) Competition by other railroads;
(2.) Regulation by statute;
(3.) Regulation by railroad commissioners;
(4.) And competition by water routes;

and that the most effective of these, with the least disturbance to all other interests, that of existing railroads included, is regulation by means of the quiet, healthy competition, afforded by water transportation. This will not mean to exclude the benefits which may be derived from either of the other three methods, but will exclude an entire dependence, or any great reliance, to be placed upon either of them.

Competition by other Railroads.—I imagine that the members of the Society will need no instruction as to the operation of this, at one time, honestly-advocated mode of relief. So long ago as the times of the elder Stevenson, the fallacy of this mode of regulation was exposed by him, in the historic saying, that, "where combination is possible, competition is impossible." And in truth, have we not all seen that process gone through with, dozens of times since then—the construction of a rival road, at great sacrifice to the builders of the road; its opening for traffic; the cut in rates; the railroad war; the exhaustion following the war; the combination of the leading owners yet at the front (the smaller and weaker owners having long since fallen out of the ranks and been reckoned among the lost, killed or wounded); the restoration of rates, they being then placed, at "what the traffic will bear;" the united front now making war, without declaring it, and foraging upon the public, foraging upon each place all "it will bear;" the appeal and squirming of the public, hither and thither, for relief of some sort and from some-

where; Granger legislation, more rival railroads, the cry for help, help; riots, arson, bloodshed. The picture is horrible enough without going further. Let it be noted, however, before passing, that the expression: "all that the traffic will bear," which is one of the railroad man's own making, sufficiently indicates how ready these servants of the public are, in the greed and thick of the battle for superior existence, "to kill the goose (in this case the public) which lays the golden egg." The form of words quoted encourages them to squeeze her all she will bear, and how easy it is, in such event, by a trifle of excess of squeeze to squeeze the life out of the patient goose, instead of expressing a stream of golden eggs of maximum weight and volume, it is not necessary to argue to the attentive reader. Of all the vaunted methods of relief that have been or can be suggested, rival railroads are probably the least efficacious and most delusive. In too many cases the face behind the mask is that of the shrewd "professional projector of railroads," drawing his strength and sinews of war from more or less deluded victims, many of whom he will at a later day leave in the lurch, and share not with them the money received for ceasing to pester the old-time established competitor.

Regulation by Statute.—And, it might be added, as such statutes are controlled by constitutional limitations, and are construed and enforced by the courts. Freight transportation has been a subject of legislation, to date, almost wholly by the several States, though some congressional action has been taken, notably the act of October 1, 1872, as to the transportation of live animals, and the "Inter-State Commerce Bill" is now (January, 1885) under discussion at Washington.

In the Commonwealth of Massachusetts, whose legislators have discussed "the railroad problem" as much as those of any State, probably, enactments on the matter of freight transportation, surviving on the statute book, are, after all, but few in number. Five sections cover it all, with three more governing the transportation of milk. Corporations must give receipts for freight, all persons and corporations must receive equal facilities, merchandise must be forwarded promptly, the "Short Haul" enactment, and a fifth section enacting fines and penalties, which many regard as a needless section, these are the five sections above referred to.

I am a believer in indirect legislation, that is to say, in using the powers of the law-giver for the establishment, mainly, of wholesome

general principles, and leaving it to methods other than by enactments, to apply those principles to the special and multifarious cases as they arise in the life of the community.

As an example of the establishment of such a general principle by statute, and as an example of one of the wisest and most beneficent laws enacted with reference to matters of freight transportation, I give the Massachusetts "Short Haul" law in full, being section 190, Massachusetts Public Statutes:

"No railroad corporation shall charge or receive for the transportation of freight to any station on its road a greater sum than is at the time charged or received for the transportation of the like class and quantity of freight from the same original point of departure to a station at a greater distance on its road in the same direction. Two or more railroad corporations whose roads connect shall not charge or receive for the transportation of freight to any station on the road of either of them a greater sum than is at the time charged or received for the transportation of the like class and quantity of freight from the same original point of departure to a station at a greater distance on the road of either of them in the same direction. In the construction of this section the sum charged or received for the transportation of freight shall include all terminal charges, and the road of a corporation shall include all the road in use by it, whether owned or operated under a contract or lease."

Let us examine this section in detail; That no *greater* sum be charged for the short haul than for a longer haul, the law requires; (1) a like class of freight; (2) a like quantity of freight; (3) the same original point of departure of the freight, whether destined for the long or for the short haul; and (4) a measurement of the hauls from this point in the same direction. Nothing so simple as this statute; nothing more eminently fair on the face of it. And yet it is constantly mistaken or misrepresented. The common mode of attack is to ignore the third requirement of the law, as above given, and to launch out in sarcasm as to requiring "the same rate per mile," over a high cost piece of road, as over a prairie railroad.

Let us not be confused by such attacks, or attempts to bring a wise law into ridicule, nor frightened out of an advocacy of the short haul principle by prognostications of a great rise in through freights, claimed to follow inevitably the enactment of such a law. Massachusetts has had the law on her statute books for ten years, the law is obeyed, it gives satisfaction to all fair-minded men; it could not be removed from the statute book if it were tried to remove it. In the absence of such

law, railroads are protected in doing business at a loss to some points, while engaged in an unreasonable competition for traffic which does not naturally belong to them. To recoup themselves for such loss, the absence of this law permits them to, and they do, tax and forage upon the country on the way to the competing point. This bears heavily upon such country; it crushes out of existence small manufacturing towns and cities; it crushes out of existence water routes at the end of the line. It is in every way detrimental to the interests of the people. The short haul law is one of the few enactments relating to freight transportation which are good and advisable as a regulator of freight rates.

But on general principles, the less legislation attempts in direct control of railroads the better for the country. It invites a meddling with the legislative functions by what has been called "the lobby." It brings upon the country the evils inherent to the worst forms of lobby activity. As a rule, it is, moreover, ineffectual, though productive of ever so loud-mouthed legislative thunder. To replace it in part, to cause it to be exercised less often, and to give it more strength at those times when it needs must be exercised, there has been evolved the third method we have set out to consider.

Regulation by Railroad Commissioners.—As there are two kinds of restraining legislation, the one directly forbidding certain acts, under pains and penalties, the other enacting certain general principles, in themselves just and equitable, and in pursuance of which, the acts to be legislated against, pass out of existence; so there are, similarly, two kinds of Railroad Commissioners; the one kind clothed with arbitrary powers, authorizing them to enact rules, orders or regulations, even to the fixing of prices for the service of railroads, the other kind, an advisory board, one patient and long suffering, hearing complaints, weighing the rights and duties of all concerned, recommending courses of procedure, which it is believed will remedy the evil complained of; in case of unruly parties, who decline or neglect to be guided by such recommendations, acting under the painful necessities of the occasion, by reporting the facts to the Legislature and devising with it a special enactment to meet the specific case in point. Such is the Railroad Commission of the Commonwealth of Massachusetts, the efficacy of whose organization has been shown by 15 years' experience. It is a focus for the concentration of public opinion, that power hardly less capable than that of the Legislature itself. And, as we have seen, such

a railroad commission has the power of the Legislature in reserve to enforce all proper recommendations. I will yield to no one in giving due credit to the utility of a properly organized and properly constituted Railroad Commission. Nor do I ignore the efficacy of wise laws upon the statute book. Nor the powers of competition, where combination is not possible. And it is for the very purpose of creating just such a competition, which is more powerful, more natural, more advantageous to the whole people, than any other regulation of freight rates, that I argue for the construction and improvement of public water-ways, and for what we have called the fourth method of regulation.

Competition by Water Routes.—Many a one has never thought of the distinguishing and essential difference between railroad and all other kinds of freight transportation; the one, that in railroads alone, the owner of the vehicle, and at the same time the "common carrier," is also the owner and exclusive occupant of the track. In the early railroad charters it was contemplated that the railroad company should furnish an improved track only, and that the use of such track should be open to the public, upon payment of toll, following the custom then in vogue with respect to turnpikes and canals. Of course, it was soon seen that such use of the track was incompatible with safety or regularity of transport, and it was forever abandoned. So that the operation of a railroad has become a business of such complexity as to ill fit it for operation by the State, and State ownership of railroads will find few advocates in this country. But the State ownership of a navigable canal, or of a navigable river, is quite another matter. These are in effect but other kinds of highways, in which the scows, tugs and steamers of the public take the place of vehicles and draught animals, while an improved or natural water-way takes the place of the road surface, and which may well be as free of toll, say some, as are the highways of to-day. Such is certainly the tendency of modern times. Not long ago the tax gatherer sat at the gates of the cities of the land and took tribute on all that passed, either in or out. His familiar hencoop-like domicile was a known land-mark along the turnpike, and at either end of the bridge that crossed the river. But like tallow-dips, perruques or snuff boxes, all these are passing away. The world has outgrown these petty imposts, levied from step to step, throughout the country, and a free water-way for water-borne commerce is a work of the civil engineer, to be paid for by the State, or by the United States Govern-

ment, worthy of the times we live in. If not made free from the start, the proper aim should certainly be to free the same in course of time. It is such a water-way, designed to hold and increase the supremacy of the City of New York as the chief commercial market on this continent, that the paper of Mr. Sweet sketches in rough outline.

It is not unreasonable to suppose, on the other hand, that such a work could be built as a commercial undertaking, and could be made to return the proper interest on its cost when once completed. But of this the present writer naturally knows nothing. To speak with any conviction on such a theme would demand a close study of the data involved.

It has been remarked that the propriety of spending $150 000 000 to give Western products a water route to the sea may well be questioned, when something like $\frac{1}{10}$ of that sum has already opened such a way, via the jetties at the mouth of the Mississippi. But it is extremely difficult to divert commerce from its accustomed channels. One might suppose, thinking of the jetty channels to the sea, that the projected Hennepin Canal, designed to connect the Great Lakes with the upper Mississippi River, was intended to carry loaded vessels from the Northern lakes down past St. Louis to New Orleans, whereas its projectors reckon on its cheapening the cost of transportation of the products of the Northwest in the opposite direction, and as it seeks the New York Market. And it is admittedly, for the purpose of holding the supremacy which the New York market now enjoys, and of keeping abreast with the demands of the new Northwest, and of the new West, that Mr. Sweet has sketched a new Erie Canal; probably not one whit more in advance of present and immediate needs than were the plans of DeWitt Clinton when he argued for the Erie Canal in 1815 or prior thereto.

As I set forth in the beginning, I have spoken of the canal suggested by Mr. Sweet mainly as it would be a regulator of freight rates, and not as it would, by its own usage, cheapen freight rates. This has been, not because I do not anticipate that such a canal would carry millions of tons at a rate defying competition, but because without close study of available data, I feel that I could add nothing useful to this part of the discussion. As a regulator of freight rates, a canal may exert a most potent effect, even though (passing to the extremes of argument) it did not carry a pound. It would suffice, that it stood ready to carry freight at the same or at a shade lower rates than its more

nimble competitor. Whence the familiar argument of the uselessness of canals, based on the annual returns of the statistician, which show how much more the railroads have carried during the year than did the canal, becomes fallacious. The Old World learnt the lesson some years ago, and has been very active in the construction of internal water routes. I have no fear that we will not in due time be equally awake, or that we shall willingly do without these greatest of cheapeners of raw materials and of food for the people.

J. NELSON TUBBS, M. Am. Soc. C. E. (by letter).—I regret that my engagements are such as to render it impossible for me to contribute to this discussion at this meeting. Had time permitted, I should have presented objections to the proposed project on these grounds:

1st. The total inadequacy of the provisions for a water supply on the long levels.

2d. Its economic aspect.

The evaporation and percolation on one of the proposed long levels would reach such an enormous quantity as to require very large and special devices to maintain navigation at all. From a hasty reading of the paper, I am satisfied that this element of the problem has not had such a critical consideration as it deserves. Should the discussion be continued at some later period, I shall be pleased to join in it.

T. C. KEEFER, M. Am. Soc. C. E.—I am not prepared at all to discuss this question; certainly do not wish to consider it in any way in its strategical aspect. I think the rivalry is purely a commercial one between Canada and the United States, as regards carriage by water. My own opinion is, according to the statistics given in Mr. North's paper, that we will soon require all the lines of transportation, both by water and rail. As regards the St. Lawrence River, I may state that we find it is better to keep the large vessels or propellers on the Lakes, where they can move faster and make more trips in the season of navigation. Very few descend below Kingston, and from there to Montreal barges are used. The barges are loaded at Kingston from the vessel and taken down the river, and business is done more economically in this way than could be done by taking the lake vessels down. These lake vessels are too expensive craft to go in the river navigation below Prescott, and, of course, not large enough to go through to Europe, and we

cannot yet give them enough return cargo to make their descent to Montreal profitable. The reason we have done so little business in the St. Lawrence, is that we are only now able, through the dredging done below Montreal, to bring up the largest class of vessels; small (3 000 ton) steamers could not compete with New York. When the Canadian Pacific Railroad is completed through to Montreal we will have another large factor in bringing down material to the St. Lawrence River, to the advantage of Montreal. Ninety per cent. of the tonnage arriving at Montreal from the sea is steam. Steam is more suitable to this route, and it also obviates the expensive towage system. The towage has become so expensive as to render it intolerable to sail vessels large enough to compete with the steamers, so that we are doing our business nearly all in ocean steamers, and the fact that Montreal brings less wheat to the seaboard than Boston or Baltimore is because it is brought there only for export. I do not know how much they export from Boston and Baltimore, but as a matter of fact, the number of steamship lines from Montreal to Europe are more than those of Baltimore, Boston and Philadelphia put together. Montreal stands next to New York in the number of her transatlantic steamship lines, and that notwithstanding she has only six months of the year of navigation, while these other ports are open all the year round. That must be due to her geographical position and to the rapidity with which vessels that do come in there are loaded. The Welland Canal is only able to pass vessels with 12 feet draught; but all structures at terminal points are for 14 feet, and it is only necessary to raise the lock levels to give 14 feet throughout. The Welland Canal will not pass the largest vessels on Lake Erie, the dimensions of which have been increased every year since the dimensions of its locks have been fixed; we can take a propeller about 255 feet long, over 40 feet beam, and drawing 12 feet of water. The deepening of the Welland and enlargement of the St. Lawrence canals go on very slowly, because the commercial interest is not as strong as the railway interest, which at present has taken all the money we have got to devote to public works, and the Government is so deeply in with them that it will probably see them through first. With respect to Mr. Sweet's paper, my opinion is that if the canal he proposes is carried out, it would effect, as regards cost of transportation, all that he claims for it. It would let out the lake vessels not only to New York, but to other ports on the coast besides New York. But a canal of that size, which would pass the

largest lake vessels, would also enable you to do what we are doing on the St. Lawrence: use barges for the New York business from Buffalo to New York. The larger the canal is for the vessel that navigates it, the more easily and cheaply it would be navigated; therefore, if you have a ship canal in which you could run barges which would not be as large and heavy and unwieldy as the propeller, I think the result would be that the grain business for export would be transferred, as it is now, into these barges at Buffalo, and taken around New York harbor in them as floating warehouses to any ship to be loaded there, and in that way unloaded at less expense. I do not know the exact manner in which your grain business is done by railway—to what extent it remains in the elevators; but we cannot afford to store up an immense quantity of wheat during our long winter season. We find that the grain that does come by rail to Montreal has to be put in barges as the cheapest way to get it on board the steamers. The grain is taken out by elevators and from them turned into barges, and when we get elevators such as the Pacific road are building now, it is expected that barges will still be required, because these large ships cannot go to the elevators. I don't know to what extent they do so here. Our earliest arrivals from sea in April or May will probably be loaded from the elevators; but after that the grain will keep the water from Lakes Michigan and Superior to Liverpool, because it can be water-borne from the western lakes to Montreal profitably, at half the cost of transportation by rail.

Mr. Simon Stevens gave the results of an inspection of the Caledonian Canal, and stated that a speed of from 7 to 13 miles was attained upon that canal. He also described the method of shore protection there, which was by large, rough quarry stone, not regularly laid, but pitched upon the bank. He also suggested the great difficulty in navigating, with long vessels, a canal whose curves were not of extremely long radius.

Robert L. Harris, M. Am. Soc. C. E.—In reference to what has been said as regards the diminishing ratio of freight carried by the canal, one point seems to me quite clear. The Erie Canal has been run under the State. It has no soliciting agents; the railways have had agents protecting their interests and working against the canal. If that canal had been operated by a company the railroads could not have

held their own against it in the matter of slow freight. Mr. Chanute's paper speaks of using the canal boats with some kind of small engine. It seems to me there is weight in this. There is one thing that is patent to every man, and that is that the present canal is not worked anywhere near up to its full capacity. With these small engines it could be worked to nearer its full capacity than it is at present. Mr. Chanute's idea seems to me to be of far more value than one would think it to be when compared with this stupendous scheme.

THEODORE COOPER, M. Am. Soc. C. E.—I do not believe that any system which requires the same vessel to carry a cargo over lake, canal, river and ocean routes will be an economical one. The vessel that is designed to carry freight economically from Liverpool to New York City, Boston or Quebec, would not be adapted for the lake, river or canal, or *vice versa.*

Ocean, lake, river or canal are three entirely different systems of navigation, and require for economy different forms and sizes of vessels.

Neither do I believe it necessary for economy that freight should go in bulk from the extreme west of our lakes to Liverpool or other foreign ports.

With suitable provisions for transfer, as is largely done now by lake to railroad and railroad to ocean steamer, I believe higher economy can be obtained than by the continuous voyage in one vessel.

The great difficulty in our canal is the fact that it does not have the same organization for obtaining and transferring traffic that other lines of transportation have found to be absolutely necessary.

F. COLLINGWOOD, M. Am. Soc. C. E.—A prominent authority has laid down the rule that the most economical size of vessel for a given trade, is that which has a capacity of one ton for each mile it has to traverse—so that vessels crossing the ocean should measure at least 3 000 tons.

Taking that rule, vessels navigating between New York and Chicago or the upper lake ports, should measure about 1 500 tons; and if the depth of water in the canal would allow, a tonnage greater than this would, doubtless, result in increased economy.

The most desirable size for the canal prism can only be arrived at by a careful comparison of the interest and maintenance account—with

the probable traffic, and the saving to be effected. The *width* of prism is of quite as great importance as the depth, as vexatious delays are sure to occur in navigating large size vessels in a narrow water way. I was at one time delayed two hours in passing through the channel connecting Keweenaw bay with Portage Lake, in Michigan. The vessel was one of the large lake steamers, and by some error in steering, her bow was run into the right bank. She was backed off and the next move ran the stern into the left bank: and this process was repeated indefinitely until a tug came and pulled us into position. I believe this experience has not been an uncommon one in the Suez Canal.

E. SWEET, M. Am. Soc. C. E.—This discussion of the canal improvement, roughly outlined by my paper, shows a gratifying interest on the part of members of the Society in the subject, and ensures the thorough consideration of its merits necessary to settle its status as a public question. It has presented some questions upon which I desire to say a few words.

Mr. Tubbs expresses the opinion that the rate at which it would be necessary to feed the canal from the lake in order to supply the lockages and the waste from evaporation, percolation, &c., renders the project impracticable. This is a fundamental objection, and if valid, is, of course, fatal to the project. Experiments made in the course of the resurvey of the Erie Canal in 1876, show the average loss from evaporation, filtration and leakage at structures in the present canal to be about 160 cubic feet per mile per minute.

The enlarged canal would lose from evaporation in proportion to its width, or 2½ times as much as the present canal, and would lose from filtration and leakage, assuming a like quality of construction, as the square root of the cube of its depth divided by the like function of the present canal depth, or 4.12 times the loss from these sources in the present canal, and we may safely assume the entire waste in the proposed canal at four times 160 feet, or 640 feet per mile per minute. The quantity of water required for lockages, assuming 100 per day, and the greatest lift 25 feet, would be 46 900 cubic feet per minute. The problem of water supply, therefore, consists in providing this amount of lockage water which is constant throughout the canal, and to provide, in addition, for the losses from evaporation, filtration and leakage on the canal proper, from Buffalo to Utica, from which point to tide-

water the natural drainage of the Mohawk River is ample for all requirements. The losses on the 233 miles of canal, at 640 feet per mile, aggregate in round numbers, 150 000 cubic feet per minute. Adding 50 000 cubic feet for lockages, we have 200 000 cubic feet per minute as the quantity of feed water required by the improved canal.

To supply this feed in part, the whole water supply of the present canal west of Utica is available. It amounts to 65 000 cubic feet per minute, reducing the quantity required from Lake Erie to 135 000 cubic feet per minute.

The water-way of the proposed canal would have a sectional area of about 2 500 square feet, in which the above quantity of feed water to be drawn from Lake Erie would produce a current of 54 feet per minute, or about $\frac{6}{10}$ mile per hour. This rate of current would increase going eastward until reaching the long central level upon which the local supply would be nearly equal to the losses, and across which the current would not exceed $\frac{3}{10}$ mile per hour. This current is in the direction of the heavy traffic, and would be a benefit rather than a hindrance to navigation.

A very simple mathematical investigation shows that in a water-way carrying loaded boats in one direction, and light or partly loaded boats in the other, any current in the direction of the heavy traffic less than the difference in speed of the heavy and the light boats lessens the time of a round trip, and therefore benefits navigation, the greatest benefit being derived from a current equal to half the difference in speed through the water going up and going down.

It is therefore clear that on this canal where so large a disparity is likely to exist between the east-bound and the west-bound freights, no hindrance to navigation need be feared on account of the feed water current, and it is probable that a considerable addition to the feed necessary for lockages and waste would be found needful to give the most beneficial current to aid navigation.

I wish to give a moment's consideration to the estimate of Mr. Van Buren, which proceeds from erroneous premises. It assumes the cost of the present canal to have been about $49 000 000, which is 50 per cent. more than its actual cost, as shown by the records of the Canal Department of the State. Those records show that the enlargement of the canal begun in 1835, and finished in 1862, cost $31 834 000.

The original canal cost $7 143 000, but in constructing the enlarged

canal the structures of the old canal were discarded, and its route was almost as generally disregarded as the route of the present canal is by that of the proposed ship canal. Its cost should therefore not be considered in estimating the cost of converting the Erie into a ship canal. But if we add its whole cost to that of the enlargement, and add all the interest on all the loans for constructing and enlarging this canal, we shall need to add a part of their principal to arrive at the sum assumed by Mr. Van Buren. Taking, however, the actual cost as a basis, and applying the principles he adopts, we arrive at an estimate of $127 000 000, very near the smallest sum named by me as its probable cost.

Beside the lessening of the interest charge due to this important modification of Mr. Van Buren's estimate of cost, it is quite certain that the rate of interest would not exceed 3 per cent. if the work were upheld by the credit of the State or the National Government; applying this rate instead of 5 per cent., the rate adopted by him in his estimate, corrected on the basis of the present canal's actual cost, gives the interest charge $3 810 000 instead of $12 000 000.

He also estimates maintenance too high. The maintenance of the present canal costs about 1¼ per cent. of the cost of constructing it, and upon this basis the estimate for maintenance should be reduced from $4 000 000 to $1 750 000, and thus we arrive at $5 600 000 for both capital and maintenance charges, instead of $16 000 000. This is less than $\frac{3}{10}$ mills per ton mile on 20 000 000 tonnage, and little more than $\frac{1}{10}$ of a mill per ton mile on the tonnage predicted by Mr. Evans, the Nestor of American engineers.

Arguments have been made by several gentlemen in discussing this question, favoring the adoption of the St. Lawrence route for the proposed ship canal.

Apart from questions of State and National interest, and of the sentiment of patriotism, which in themselves, with most of our people, suffice to fix imperatively the location by the Hudson route, the proposed change of location would simply aid foreign commerce and defeat the chief object of the improvement, which is to facilitate the vast domestic traffic between the East and the West.

Its tonnage is now many times that of the foreign commerce tributary to either route, and this disparity is sure to increase with cheapened facilities for bringing East the grain, lumber, ores and other raw ma-

terials of the West, and sending back heavy products, and it is obviously a commerce not reached by the St. Lawrence route.

The discussion has brought out several plans for increasing the efficiency and economy of the present canal.

Mr. Chanute's plan is to make transit upon it by the use of automatic engines of small power. Had we such engines they would not accomplish the results Mr. Chanute seeks. They would not realize any approach to the lowest rate of speed he mentions—four miles per hour—with the boats now in use on the canals. These boats when loaded require 40 000 foot pounds per minute, $1\frac{21}{100}$ horse-power, to attain their average speed by animal propulsion, $1\frac{1}{2}$ miles per hour.

The horse-power required to run them at a faster rate increases as the cube of increase in speed (because resistance to propulsion in water varies as the square of the velocity, and the work varies as the resistance multiplied by the velocity). To run them 4 miles per hour, or 3 times as fast as the animal rate, $1\frac{1}{2}$ miles per hour, would require $1\frac{21}{100}$ H. P. $\times(3)^3$, or 31.7 horse-power, a power to which the engines suggested by Mr. Chanute would not be adapted.

It is the essential defect of small canals that the small boats which can alone navigate them have too large an extent of immersed surface and consequent resistance for the tonnage they carry. Thus a 2 500 ton steamer has little more than four times the immersed area and resistance of the largest boat of like model capable of navigating the Erie Canal and which would carry but 200 tons, *i. e.*, the larger vessel under like conditions would have but one-third the resistance per ton of the smaller one, and would have the further advantage of concentrating its power in one engine, while equal tonnage on the smaller boats would require twelve. It is this principle that the immersed surface and resistance relatively decrease as the size of the boat increases, which is the characteristic feature of water transportation and the principal reason for the superior economy of large vessels.

Mr. Chanute misapprehends the relative proportions of the present and proposed canal and the size of boats navigating the former. These boats are $17\frac{1}{2}$ feet wide and have about one-fourth the cross-sectional area of the canal water-way. The section of a steamer 40 feet wide would bear a slightly smaller ratio to the section of the proposed canal 100 feet wide at bottom with 2 to 1 side slopes.

Mr. Clarke's proposal to keep the present canal open through the

winter can hardly be intended seriously. To keep open a body of water having over six square miles of surface radiating into space and having a continual influx and discharge of over 100 000 cubic feet of water per minute in a climate cold enough to frequently cover this surface with four inches of ice in a day, requires an amount of heat that can be expressed in figures and to which the beneficent processes of nature are adequate, but which cannot be effected artifically without controlling radiation by roofing in and enclosing the whole structure. If it were enclosed it would take 1 000 horse-power boiler capacity, 20 000 superficial feet of steampipe, and a daily consumption of 60 tons of coal for each mile of the canal. As the lakes and rivers would be closed, there appears no adequate motive for such an expensive struggle against climate.

With reference to Col. Merrill's suggestion that the dams of the Mohawk should be stationary, it should be considered that the topography of that valley is characterized by wide areas of valuable flat lands, and to preserve them from floods during the period of cultivation it would be necessary that the crests of some of the dams should be adjustable within moderate limits, but not that they should be movable down to the level of canal bottom.

Mr. Corthell's argument in favor of railroads against canals rests, as I conceive, upon two fallacies which brief consideration will, I think, make clear.

The first is the assumption that railway competition has produced the low rates by the water routes, and the second the inference that because railroads have displaced many small canals constructed for local traffic before the introduction of railroads, the latter in all cases and circumstances best answer all the demands of transportation.

As to the reduction of rates, the beginning of the period covered by Mr. Corthell's generalization (1857 to 1883) antedates the completion of the Erie Canal enlargement and the principal improvements of lake harbors and channels. It marks an early stage of the development of the western country tributary to the lakes, made possible by the canal, and it covers the period of inflation due to the war and paper currency and of increased canal tolls from 1865 to 1870, during which ten years the tolls collected on the Erie Canal aggregated more than the entire cost of the enlarged canal.

Notwithstanding the high tolls, both canal and lake freights, except

during the period of inflated values, 1861 to 1866, gradually diminished with the development of the country and the progress of the lake improvements. That they have been uniformly much less than railroad rates, and that the rail rates have uniformly advanced from 25 per cent. to 100 per cent. the moment water navigation closed, shows clearly that is not to railroads that the low rates are due.

Mr. Corthell's inference that because railroads have displaced many small canals depending on local business, therefore all artificial water-ways of whatever size and however circumstanced are inferior and must yield to railroads, is equally fallacious. This inference ignores the necessary limitations of the two methods of transport.

The railroad is incomparably the most important instrument of internal commerce, because at moderate cost it can be run almost anywhere, thus affording the means of universal development, and because by the rapidity of movement that it effects it becomes indispensable for the transport of passengers and valuable and perishable freight. It has, however, limitations of capacity and economy.

Experience shows that no economy can be gained by wider gauge or heavier rolling stock than is adapted to tracks of standard gauge. Capacity can be increased only by more tracks and more trains. Increased economy in rail transport can, therefore, only be looked for in new economies of railway construction, operation and maintenance.

An inspection of the reports of the New York Central Road, moving the largest tonnage per mile over the most feasible trunk route in the country, shows that in the present condition of things the operating expenses, repairs and maintenance charges applicable to freight amounted in 1883 to $6\frac{7}{10}$ mills per ton per mile.

If we deduct the entire cost of handling freight, agents and other station expenses as chiefly chargeable to local freight, we have for the cost of transporting through freight $5\frac{1}{2}$ mills per ton per mile without capital charges, and it may safely be said that no railroad has yet been able to contribute anything to capital charges from a 5-mills tariff.

The limitations of economical water carriage are quite different. The economy of water transit increases within wide limits, with the size of the vessel employed, and the capacity of artificial water-ways increase nearly as the cube of the depth of channel if the width be duly proportioned.

The contributions of Gen. Poe and Mr. Drake to this discussion show that increasing the depth of lake channels and harbors from 9½ to 16 feet, and the use of steam has reduced lake freights two-thirds, and Mr. Drake's statistics show that steamers carrying 2 500 tons on the lakes make a profit at less than ¾ of a mill per ton mile.

Though a canal is operated at greater cost than an unlimited expanse of water, the increased economy due to increased depth obviously rests on the same principles and applies equally to both. This is shown by the enlargement of the Erie Canal, which increased the capacity of boats from 40 tons to 240, and reduced the cost of transport $\frac{7}{10}$.

The only conditions of success for such a canal as here proposed, are a large volume of tributary freight and an easily practicable route, and no great canal has been seriously thought of presenting any approach to the volume of business it offers, and few presenting so slight engineering difficulties.

The discussions by Gen. Poe and by Mr. Drake show, in a strong light, the increased volume, speed and economy of the lake freight service due to the lake and harbor improvements, which have increased the available draught through the channels governing the loading of lake vessels to 14 feet.

It is pertinent to this discussion to consider the effect of securing on the lakes 16 feet draught, which is contemplated in the enlarged canal I have suggested. A typical lake steamer, loaded to 14 feet draught, carries about 2 200 tons, and loaded to 16 feet draught would carry 2 700 tons, or 500 tons additional. Such a vessel, drawing 14 feet, with engines of 1 000 indicated horse-power, can make 12 miles per hour on the lakes.

The resistance of vessels of like model and like smoothness of surface, moving in an unlimited expanse, as the lakes practically are, varies as the square of their velocity and as the area of their immersed surface. The immersed surface of the vessel above described, when drawing 14 feet, is about 14 000 square feet, and when drawing 16 feet is about 15 100 square feet, or less than 8 per cent. more surface, which represents the increased resistance and cost of fuel, for 23 per cent. more freight in the same vessel at the same speed.

If 1 000 horse-power be assumed as the full indicated power of the steamer's engines, we can readily determine the reduced speed due to loading two feet deeper.

The formula for motion of vessels in an expanse of water is $R = asv^2$, in which R represents the resistance, s the immersed surface, v the velocity, and a the constants for friction and stream lines, which may obviously be considered the same for slight differences in draught of the same vessel. Let v and v' represent the speed at 14 feet and 16 feet draught respectively, and assuming the immersed surfaces given above for these depths, we have; for the same resistance $14\,000av^2 = 15\,100av'^2$, and for the same work or horse-power $14\,000av^2 \times \frac{v}{375} = 15\,100av'^2 \times \frac{v'}{375}$.

$$\text{Or } v = 1.028v'.$$

$$\text{For } v = 12;\ v' = 11.71.$$

That is, with the same power the vessel loaded with 500 additional tons would be retarded less than 3 per cent. in speed, or lose less than two hours in the voyage from Chicago to Buffalo.

Thus, the same vessels with the same crews, if the channels governing the draught of lake vessels be deepened 2 feet, will carry 23 per cent. more freight without material increase of cost or loss of time.

Another important consideration is the speed attainable or permissible in the navigation of the proposed canal. The speed theoretically attainable may be determined by formula for the resistance of vessels in narrow channels deduced from the experiments reported and discussed in my paper on the subject published in No. 189 of the Transactions of the Society.

The formula for resistance to propulsion in a narrow channel for a vessel whose co-efficients of resistance in an expanse are known, is $R = \frac{av^2s}{r - .597}$, in which R represents resistance, v velocity in miles per hour, s immersed surface of vessel, r the ratio of the cross section of the channel to the immersed section of the vessel, and a the co-efficient of resistance for the type of vessel considered.

Assuming the same vessel as above described with a maximum engine capacity of 1 000 horse-power, producing in an expanse a speed of 12 miles per hour, if the efficiency of the engines be taken at 65 per cent., the value of a is 0.145. The ratio of the proposed channel to the immersed section of the vessel r is about 4.20, and as the immersed surface s is 15 000 square feet, the formula for resistance in this case becomes:

$$R = \frac{(0.145v^2)\ 15\,000}{3.6}.$$

As the available efficiency of the engines is 650 horse-power, and as the horse-power required to overcome the resistance R at the velocity v in miles per hour is $R\frac{v}{375}$, we have for the greatest attainable speed in this case :

$$\frac{(0.145v)}{3.6}\ 15\,000 \times \frac{v}{375} = 650\ ;\ \text{or}\ v = 7.4\ \text{miles per hour.}$$

I think, however, that 5 miles per hour, requiring little more than one-third the full efficiency of the vessel's engines is as high a rate of speed as would be permissible in the narrow channel of the canal. That is found to be the proper rate in the present canal for steamers whose size bears a like relation to the size of the water-way, and is generally adopted on large canals as the maximum rate.

That such a rate is not realized in the Suez Canal is due to obvious reasons : The section of its water-way is little more than twice that of the larger vessels navigating it, its sandy slopes are entirely unprotected and are constantly washed into the channel by displacement waves, and the tidal currents at the Suez end are a source of serious delays.

The portion of this canal having a narrow, artificial channel extends from Buffalo to Utica, about 230 miles, and at 5 miles per hour it would require 46 hours' running time, and allowing twenty minutes detention at each of the eight locks to be passed, the trip over this section would require 49 hours. From Utica to New York, about 260 miles, the larger water-way afforded by the Mohawk and Hudson Rivers would permit an average running rate of 10 miles per hour, requiring 26 hours, which, with an allowance of 10 hours' detention at the locks of the Mohawk, would make the duration of the voyage from Buffalo to New York 85 hours. The effect of this improvement would be to extend an arm of the sea nearly to the centre of population of the whole country.

It would overcome the fatal difficulty heretofore besetting the water route due to the delay and cost of breaking cargo in transit, as it would enable continuous voyages to be made from all lake ports to the sea at an actual cost for transportation not exceeding $\frac{1}{10}$ of a cent per ton per mile. Upon this line of transportation, affording the simplest possible facilities for collecting and distributing the raw materials and products of manufacture, population would naturally concentrate.

There is no part of the world where so favorable conditions exist for the heavier kinds of manufacture as would be here presented, on ac-

count of the unequalled cheapness of food supplies, cheapness of raw materials, and the cheap and ready means of reaching all markets at home and abroad. These conditions furnish the necessary elements to ensure the rapid growth and continued prosperity of the manufacturing and commercial towns already so numerous along this national artery of commerce.

I think it may safely be predicted that railroads are now giving us the lowest rates of transportation for the class of business to which water carriage is suited that can for a long time be expected from them, as their fierce rivalries have induced rates below cost, at a time when extremely low prices prevailed for everything entering into the cost of their maintenance and operation.

The future prosperity of the railroads depends on the continued growth of population and business activity in the country, for it is this development which will ensure the growth of the class of business which they alone can do, and upon which their profits are made. It is by this influence upon the general development of the country that this improvement would benefit the railroads as much as any industrial interest of the country.

JOHN D. VAN BUREN, JR., M. Am. Soc. C. E.—Mr. Sweet declares my estimate of the probable cost of the proposed ship canal, "proceeds from erroneous premises" in assuming the cost of the present canal to be about $49 000 000, and further says "the records show that the enlargement of the canal, begun in 1835 and finished in 1862, cost $31-834 000. Proceeding by methods similar to those adopted by me, he estimates the probable cost of the proposed work to be $127 000 000, in place of $240 000 000. This difference, or error, of $113 000 000 is perhaps not greater than the usual discrepancies between the estimates of advocates of such enterprises and the actual cost of the works; but it is important to make the correction now if possible.

Now, any one familiar with the history of the Erie enlargement knows that, notwithstanding the fact that the Legislature of 1862 declared the canals completed, they were not then completed. This was especially true of the Erie Canal. In 1863 there remained (on the Erie) 13 locks to be built (doubled), the last one finished in 1874; 75 miles of slope wall benches to be excavated and slope wall to be extended to the bottom, numerous bridge abutments and bridges to be built, very ex-

tensive and expensive improvements to be made in the harbor and City of Buffalo, at Troy and Albany, &c., in order to bring the canal to a state of completion, affording its present facilities (Reports of State Engineer, 1863 to 1876). For this work of completion there were expended up to 1876, nearly $9 000 000, under the heads of enlargement of the canals, "extraordinary repairs," and other accounts. The cost of the Erie Canal up to 1876 is shown by the following figures, taken from the official reports:

*Cost of original canal, exclusive of interest.....	$7 143 789 86
†Cost of "enlargement," exclusive of interest.....	33 609 760 60
‡Cost of completing enlargement "extraordinary repairs," &c.....	8 407 436 47
	$49 160 986 93
§Interest during construction, original canal.....	1 883 666 14
†Interest during construction, enlargement.....	8 245 227 87
Total.....	$59 289 880 94

When I assumed the cost of the present canal to be about $49 000 000, I meant the completed canal, not the unfinished work of 1862, which was a very different affair. This sum is the amount charged to construction account by the auditor, and represents the outlay by the State in building this canal. In placing the cost of the structures of the Erie Canal at $16 000 000, an itemized table (the only one available) was followed, giving the cost up to 1862. Since that date several millions have been expended for structures in *completing* the enlargement; indeed, the greater portion of the sum charged to construction account since that date has been for such structures.

The cost of the original canal has not been deducted, because, 1st,

* State Engineer, 1863, p. 189: Figures furnished by Comptroller.

† Auditor's Financial Report, 1879, pp. 70, 71: Miscellaneous items are debited and credited, and interest on deposits and investments credited to interest account.

‡ State Engineer, 1876: Construction Account of the Erie Canal, as stated by the Auditor, amounted to $49 160 986.93.

§ Committee of Legislation, 1833, quoted by State Engineer, 1863, p. 137: Total cost, including interest, is given as $9 027 456. See, also, Auditor's Financial Report, 1879, Table 80, which shows that up to 1827 the interest on loans for Erie and Champlain Canals amounted to $1 931 808.93, most of this being chargeable to the Erie.

NOTE.—It will be observed that no interest is charged on the amount $8 407 436.47, a very considerable item. It would be difficult to estimate it from the reports, and as it does not affect the estimated cost of the proposed work, it is unnecessary to do so.

much of the work and material of the old was used in the new canal; 2d, the old canal was used as a route of transportation for material, and so cheapened the new work; 3d, the cost of the abandoned work represents so much loss or capital sunk, to be charged to the construction account of the enlargement; and a similar loss would result, but four or five times greater, by abandoning the present for the proposed work. If an owner pulls down an old house which cost him $20 000, and erects one for $80 000, the capital invested is $100 000, less the value of the old material. This rule applies to public works as well, and to railroads. For these reasons I think my estimate a fair one—quite enthusiastic enough for safety.

Mr. Sweet's statement of the cost of the present Erie Canal, $31 834 000, is over $10 000 000 below the true figures, even when the cost of the original canal is omitted. Had his attention been confined to the same canal when assuming his basis, and following my methods, he would have arrived at about my figures, $240 000 000.

As to the interest charges during construction it must be considered that the cost of financial management, an important item, is covered by the rate adopted, 5 per cent., and the State would undoubtedly experience greater difficulty in floating a loan when loaded with a heavy debt.

I cannot agree with Mr. Sweet in placing the cost of operating as low as $1 750 000. It is difficult to see how a canal, in our latitude, 350 miles long, with numerous expensive locks and aqueducts, could be operated for a less sum than is required to operate the Suez Canal, which is only one-third as long, has no such expensive structures, and is located in a country where labor is so cheap.

Mr. E. Sweet, M. Am. Soc. C. E.—Mr. Van Buren's supplementary statement in defense of his estimate based on the cost of the enlarged Erie Canal, appears to me peculiarly vulnerable.

The amount I stated as the cost of the enlarged canal, $31 834 000, includes the estimated cost of completion, as well as the total sum expended to 1862, and is, I think, the fairest statement attainable of its legitimate cost.

No one should know better than Mr. Van Buren that the vast sums expended under the pretext of improving this canal during the period from 1862 to 1875, when enormous revenues were being derived from tolls, were for the most part a waste of the public money, as is shown

by the results of the investigation of 1875 by a commission, of which he was a member. It is obviously incorrect to include these sums wasted in useless jobs in arriving at a proper basis for computing the probable cost of the new canal. For equally obvious reasons the cost of the old canal should be excluded from such a basis.

To use Mr. Van Buren's illustration, if an owner wishes to replace a building with a larger one, and uses the cost of the old building to determine what he will probably expend on the new one, he would not add also the cost of some structure that may have existed on the same lot before the one taken as his basis of computation.

Of course both these items of cost must be considered in determining what the State has spent on her canals, but both are clearly foreign to the estimate in question. The suggestion that the sum required for this work is so large as to probably affect the public credit and raise the rate of interest, I think, hardly merits consideration.

As to the probable cost of maintenance, I can conceive of no safer basis than the maintenance of the present canal. The Suez Canal, with its continually shifting sands, requiring constant dredging, certainly affords no criterion for such an estimate.